

PROPOSAL FOR A CAVITY POLARIMETER AT MIT-BATES *

P. Cameron¹, W. Barry², M. Conte³, D.A. Goldberg², K. Jacobs⁵, A. Luccio¹, M. Palazzi³, M. Pusterla⁴, W. MacKay¹

¹Brookhaven National Laboratory, Upton, NY 11973, USA

²Lawrence Berkeley National Laboratory, Berkeley, CA 94720 USA

³Universita and Sezione INFN di Genova, 16146 Genova, Italy

⁴Universita and Sezione INFN di Padova, 35131 Padova, Italy

⁵MIT-Bates Laboratory, Boston MA 01949 USA

Abstract

The possibility of successfully implementing a cavity polarimeter[1] has been greatly improved by the discovery[2] of a cavity mode for which the magnitude of the Stern-Gerlach force experienced by a magnetic moment traversing the cavity varies as the square of the relativistic factor gamma, so that the signal power varies as the fourth power of gamma. In addition, the interaction of this cavity mode with the beam charge varies as the inverse of the interaction with the magnetic moment, so that the background due to the beam charge varies as the inverse fourth power of gamma. If these gamma dependencies of moment and charge interaction with the pickup cavity do in fact exist, the possibility is opened for very fast, accurate, and inexpensive polarimetry at accelerators like MIT-Bates and RHIC. In addition, it might become possible to seriously consider Stern-Gerlach polarization of beams at LHC. We present details of a quick polarimeter test at the electron storage ring at MIT-Bates, and of an extension of this test to a working polarimeter in the RHIC rings.

1 POLARIMETER AT MIT-BATES

The cavity polarimeter consists of a passive resonant cavity, which extracts and accumulates spin-dependent energy from the beam via the Stern-Gerlach interaction between the beam and field in the cavity. In the case of a resonant cavity the stored energy increases until equilibrium is attained, where the power supplied by the beam equals the power dissipated as a result of the finite cavity Q. We can write this as

$$Q \equiv \frac{\text{stored energy}}{\text{loss}} = \frac{\omega U}{\frac{dU}{dt}} \quad (1)$$

where $\omega=2\pi f$, $f=2.856\text{GHz}$ is the bunching frequency, and U is the stored energy. The rate at which polarization leaves energy in the cavity, or the signal power, is

$$\frac{dU}{dt} = \mu B \tau b n f \gamma^2 P \quad (2)$$

where μ is the magnetic dipole moment of the electron, B is the field in the cavity at equilibrium, $\tau \sim 0.7$ is the transit time factor, $b \sim 0.7$ is a bunch length factor resulting from the head and tail of the bunch being out of phase with the field in the cavity, $n=10^8$ is the number of electrons per bunch for all buckets filled and 50ma beam current, $\gamma=2000$ is the relativistic gamma factor at 1GeV,

and $P \sim 0.4$ is the beam polarization. Rearranging equation (1), we can write

$$U = \frac{Q}{\omega} \frac{dU}{dt} = \frac{\epsilon_0}{4} B^2 c^2 V \quad (3)$$

Substituting (2) into (3) and solving for the equilibrium field B ,

$$B = \frac{4Q\mu\tau b n \gamma^2 P}{\pi\epsilon_0 V c^2}$$

Where $Q=5000$, ϵ_0 is the permittivity of free space, c is the speed of light, and $V \sim 1000\text{cm}^3$ is the cavity volume. Substituting the value found for the equilibrium field into (2), the signal power is

$$\frac{dU}{dt} = \frac{4Qf}{\pi\epsilon_0 V} \left(\frac{\mu\tau b n \gamma^2 P}{c^2} \right)^2 \approx 10^{-7} \text{ watt} \quad (4)$$

or about -40dBm. In the world of small signal beam instrumentation, this is a whopping big signal. In comparison, Schottky signals are typically at -150dBm or less. It is interesting to note that the power varies as f^4 , because of the $1/f^3$ dependence in the cavity volume, so that there might be some advantage to operating the cavity at higher frequencies, and accepting the penalty in bunch length factor.

2 POLARIMETER AT RHIC

Performing the same calculation for conditions to be found at RHIC (55 bunches, 10^{11} per bunch, 50% polarization, $\gamma=266$, $Q=5000$) yields the result that the signal power is about -130dBm. Again, this is a good strong signal relative to Schottky signals.

3 CONCLUSION

While a number of issues remain to be addressed, some fairly straightforward and others thorny and difficult, the obvious course at this time is to build a simple cavity and perform the measurement. We are proceeding with this as rapidly as funding permits.

4 REFERENCES

- [1] Ya. S. Derbenev, "RF-resonance Beam Polarimeter: Part 1. Fundamental Concepts" NIM A 336, p.12-15 (1993).
- [2] M. Conte et al, "The Stern-Gerlach Interaction between a travelling particle and a time varying magnetic field" <http://xxx.lanl.gov/list/physics/0003.0003069>